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Water, Waste and Quality Management During Preparation and Processing of Vegetables

Arkansas Water Resources Research Center
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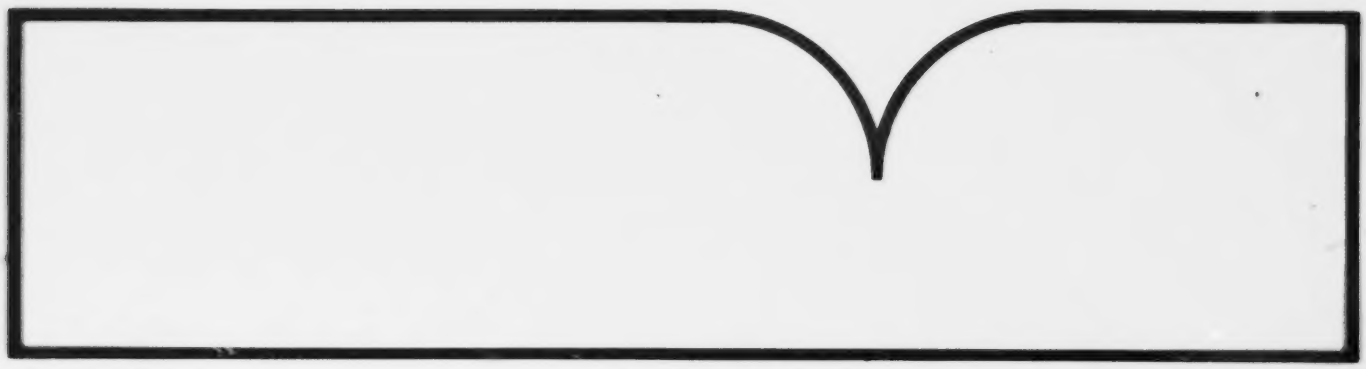

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WATER, WASTE AND QUALITY MANAGEMENT DURING PREPARATION AND PROCESSING OF VEGETABLES

by

W.A. Sistrunk

AWRRC

Arkansas Water Resources Research Center

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16. Abstract
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Arkansas Water Resources Research Center
UNIVERSITY OF ARKANSAS
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ABSTRACT

The research was designed to test and/or develop new systems of washing, peeling and blanching, develop methods of utilization of solid wastes, and find ways to reduce wastestrength of effluent without affecting quality of vegetables for processing. The highest wastestrength of effluent from vegetable processing in the region was found in plants that were canning Irish potatoes, dry beans and hominy. The high volumes of water used for washing spinach and leafy greens and the physical damage to the washed product is one of the major problems. Repetitive washing of spinach in the same water did not affect quality as long as there was sufficient rinsing after the second wash. The levels of COD, TSS, TS, SS, PO_4 and NO_3 did not build up to prohibitive levels by the reuse of water as long as adequate make-up water was added. Steam blanching, which leaches out much less soluble constituents, can be substituted for water blanching by using appropriate times and temperature for different vegetables. The greater retention of nutrients in steam blanched vegetables was demonstrated in different vegetables grown and processed under different conditions. Data from research on the canning of dry beans indicated that the high wastestrength can be reduced by shortening the soaking time, controlling the temperature of soaking and processing without blanching without changing the quality appreciably. It appears that the present method of hominy preparation and processing can be altered to reduce pollution. By dipping corn in 10% lye solution, followed by heating and scrubbing, corn can be peeled and bleached efficiently. Most of the heavy solid waste can be isolated before the final rinse of the peeled corn. The prototype leafy greens washing system decreased the use of water by 70% on spinach, turnip greens and mustard. Water quality data showed that wastestrength of the effluent from washing was reduced over 50%, as compared to industrial washers, primarily due to less physical breakage. Less nutrients were leached out in

greens washed by the experimental washer than the industrial washer. High alkalinity solid wastes from peeling Irish and sweet potatoes can be fermented and stored as long as 9 months without any great change in carbohydrates and total dry matter. There was an increase in sugar content and a decrease in starch content during fermentation. The quality of the sweet potato waste appeared to be excellent after storage when mold inhibitor was sprayed on vats. Irish potato waste storage created more odor problems unless the fermentation temperature was controlled at 25 to 30°C.

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INTRODUCTION

One of the major users of fresh water in the United States is the food processing industry. Cleaning, washing, peeling and blanching of vegetables by the present methods requires large volumes of water which carry soil, solid materials, sugars and other soluble constituents that have to be removed by screening, settling tanks, aerated ponds, activated sludge, landfills and other methods. The National Canners Association estimated that by 1980 there would be 100 billion gallons of wastewater discharged from food processing plants carrying with it 500 million tons of Biochemical Oxygen Demand (BOD) 250 million tons of Suspended Solids (SS) and 10 million tons of solid residuals (24). Changes in processing methodology (washing, blanching, cooling) and reuse of water to meet the EPA guidelines probably will reduce these original estimates significantly. Nevertheless, disposal of liquid and solid wastes will continue to be costly to the food industry and thus the consumer.

The effluent limitation guidelines require that food industries apply the best available control technology economically feasible by 1983 (12). The act strives to accomplish zero discharge, the complete elimination of all discharge of pollutants to navigable waterways as a national goal by 1985. A number of methods for reducing wastes have been established such as improved processes for degrading liquid waste, better screening of suspended solids, conservation of water, recycling of water, development of useful by-products from liquid and solid wastes, etc. (13).

Bough (7) found the composite load of water, BOD, and SS from a commercial leafy greens canning operation to be 17%, 28% and 14%, respectively of the total waste strength. Certain methods of washing snap beans can reduce water use as much as 100% (10). Variations in water use for peeling and washing potatoes have been recorded from 468 to 2500 gal/ton (2,10,35). Peas required from 432 to 1200 gal/ton of water for cleaning, washing and fluming (35).

Peeling of root crops has been accomplished by a number of methods such as hot lye solutions, steam, mechanical abrasion, exposure to flame and infrared radiation. Dry caustic peeling has been shown to remove peel with less product loss and lower volumes of water and lower BOD than conventional methods (9,13,23) In sweet potatoes, a 50% reduction in water use and BOD was reported by the dry caustic method (33).

In a comparison of four blancher designs including water, steam hydrostatic, vibratory spiral and hot-gas, the hot-gas method produced the lowest wasteload (3). The energy efficiency of hot-gas was an improvement over steam (3,26,27). However, the low capital investment of water blanchers has continued to be an attractive feature (3). Using air as a means of heat transfer for blanching reduces water use and loss of solids by leaching (17). The use of microwave blanching for vegetables retained equal or greater chlorophyll and ascorbic acid than conventional methods but it was not practical because of large capital investment and low energy efficiency (26).

Large volumes of water are required to cool vegetables after blanching. However, Bomben (5) demonstrated that either forced air plus spray cooling or forced air alone reduced solids loss when compared to water cooling. Cooling of vegetables for canning is not always necessary nor is it economically feasible. Forced air cooling was found to be as effective as air in combination with water spray although a limited amount of water prevented dehydration of the product. Blanching and cooling have been combined in recent years in a vibratory blancher-cooler (6,8).

There were four objectives of the present research as follows:

1. To develop and test systems of dry and wet cleaning of raw vegetables for processing.
2. To evaluate and/or develop new techniques of peeling and blanching for vegetables.

3. To determine the most efficient methods of (1) utilization of solid wastes and (2) reduction of BOD in liquid wastes.
4. To determine the effect of these techniques on quality of water and quality of processed product.

MATERIALS AND METHODS

Initially, a survey was made in the spring of 1975 of the processing plants in the Ozark region to evaluate the methods of cleaning, peeling and blanching of vegetables. Also, the effluent from different processing plants was monitored to determine normal waste loads during operation. From the evaluations and from discussions with management the following operations appeared to be the most critical, contributing significantly to the wastestrength of the effluent and control of solid wastes: 1) Washing and cleaning; 2) blanching and cooling; 3) high alkalinity peeling wastes from peeling Irish and Sweet potatoes, and corn for hominy; 4) removal of suspended solids from effluent; and 5) excessive use of fresh water.

Six major areas of research were pursued during the four years of the project:

I. Monitoring of water quality of effluent (BOD, COD, SS, TS and settleable solids) periodically in different plants to aid in the solution of problems that developed on different products during the application of new technology to reduce wastestrength of the effluent.

II. Research on (a) steam and water blanching (b) cooling vs no cooling of product after blanching and (c) wash water volumes with and without detergent on canned green beans, spinach, turnip greens, mustard greens and kale greens.

III. Research on bean types, including soaking times, soaking temperatures and chemical treatment to evaluate ways of reducing wastestrength of effluent from canning dry beans.

IV. Research on new methodology for peeling and bleaching corn for the manufacture of hominy to reduce wastestrength of effluent.

V. Evaluation of a new washing system for spinach and leafy greens.

VI. Research on fermentation, handling and storage of Irish and Sweet potato high alkalinity peeling wastes for animal feed.

Raw product, sampling and methods of analysis

I. The water samples were taken from different steps of operation in the processing plants to determine not only where the greatest wastestrength was produced, but effectiveness of new screening technology, chemical treatment and mechanical separators. It was from this cooperative effort with plant management and control personnel that the greatest feedback on waste management was obtained. Water samples were taken of effluent from processing spinach, leafy greens, fried shoestring potatoes, canned Irish potatoes, green beans, dry beans and hominy. The grab samples were taken from the different steps in the operation and analyzed by Standard Methods for the examination of water and wastewater (1) for Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Total Suspended Solids (TSS), Settleable Solids (SS) and Total Solids (TS).

II. The raw material for the processing methodology was obtained from three different processing plants and from plots on the Main Experiment Station, Fayetteville, AR. The raw product was prepared by sorting, washing, blanching, cooling and freezing or canning. Detailed procedures are recorded in the separate published articles (appendix A-1,A-2,A-3). For this study a small reel-type washer was adapted for use as a washer and steam blancher. Five spray nozzles were interchanged between lots to obtain 3 rates of water flow and the reel could be enclosed to serve as a rotary steam blancher. Separate studies were conducted on spinach, turnip greens, green beans and

kale to study the effect of volume of water, detergent, blanch temperature, type of blancher, blanch time and cooling on water and product quality.

Water samples were analyzed by Standard procedures (1) for COD, TSS, SS, and TS. The canned and frozen samples were rated by a 6 member sensory panel for color, texture and general appearance. Other determinations were drained weight, liquor color, ascorbic acid, nitrates, shearpress, grit and sand, and color by the Gardner Color Difference Meter. On frozen spinach and greens the analyses were confined to ascorbic acid and color.

The drained weight of canned products was obtained by draining the contents on an 8-mesh screen for 2 minutes and weighing. Liquor color was obtained by centrifuging samples of liquor and reading the optical density (OD) at 475 nm. Nitrates and phosphates were determined on a aliquot of the liquor of canned product by standard procedures (1, appendix A-2) Ascorbic acid was determined by weighing a 25g sample of product and blending in 100 ml of 1% oxalic acid, then filtering and following the procedure of Morell (22). Color was determined on both the whole processed product and a 1:1 blend of product and water by a Gardner Color Difference Meter using standard plaques to standardize the instrument. Grit and sand were determined by washing away the pulp of a 150g sample of blended canned spinach by a gentle stream of water in a 600ml beaker. The water was decanted and the grit and sand transferred to a tared pan, dried at 100°C, and weighed to obtain the dry residue. Resistance to shear was determined on 150g of the drained product using a Food Tech. Corp. Model Tp-1A shearpress.

III. The dry bean research was conducted on 3 bean types (Navy, Pinto and Red Kidney), 3 soaking times (3, 6 and 14 hours), 3 soaking temperatures (15, 25, and 35°C), 11 soaking treatments including citric and malic acids, and ethylenediaminetetracetic acid (Na salt) at 3 concentrations with tap and deionized water as controls and 3 storage times of canned product.

Detailed procedures of the research,method of processing and methods for wastewater and canned product analyses,are given in the appendix B-1).

IV. The corn was obtained from one of the local processing plants. The corn was weighed out in 200g lots and peeled by 2 methods, the standard commercial method which involves cooking the corn in a solution of approximately 1.5% caustic soda for 30 minutes and a dip method in which lots of corn were dipped in 10% lye solution for different times followed by heating in steam for different time periods. Peeling was accomplished by stirring in a perforated stainless steel basket under a spray of water. Bleaching was accomplished either by heating the peeled corn in a solution of $NaHSO_3$ or HCl. After further cooking of the peeled corn (30-45 minutes) the hominy was canned according to NCA recommendations.

Water samples were analyzed for SS, COD and TSS as described above. The canned product was rated by a 6 member sensory panel and colorand firmness were determined as described in Section II.

V. The research on washing of spinach and leafy greens using the prototype washing system obtained on a license agreement from EPA, Cincinnati, OH was conducted in the spring of 1978 and 1979. The washing system was developed by the Agricultural Engineering Department of Virginia Polytechnic Institute and was loaned to the University of Arkansas and Steele Canning Co. for testing and demonstration. The equipment was transported to Springdale, AR and installed adjacent to one of their processing lines at their expense. The capacity of the washing system is 4-5 tons/hour. Details of the design of the system have been previously described (18,36,37).

The commercial processing line normally runs 10 to 12 tons/hour of spinach and leafy greens. During the experimental runs 1/3 of the product 3-4 tons/hour was diverted to the experimental washer. Water samples and raw

product samples were taken at 30 minute intervals from 4 sites from both commercial and experimental washers. Water samples were sealed in polypropylene sterile bottles and preserved until analyses were made. The raw product samples were collected at the discharge end of the washers and transported to the Horticultural Food Science pilot plant (6 mi distance) for water blanching, cooling and canning and/or freezing. Standard commercial procedures were used for these operations. Separate samples of canned product washed by the two methods could not be obtained from the processing plant since all washed product was combined before proceeding to the water blancher.

The methods for wastewater analysis have been described under section I above. The types of determinations and methods of analysis on the canned and frozen product are described under section II above. Total plate counts were conducted on water samples by standard methods (1).

VI. This research has been conducted over a 4-year period; that is , various phases of the work. Initially, studies were conducted on time and temperature of fermentation with and without aeration by an air pump. A major study during 1976-77 involved time and temperature of fermentation of Irish potato wastes under aerobic and anaerobic conditions. Bacteria were isolated and identified during the stages of fermentation at different pH levels. Part of the results of this study are recorded in a Master's thesis, Appendix D-3, and two published articles (Appendix C-1, C-2).

RESULTS AND DISCUSSION

I. Monitoring of water quality of effluent.

The effluent from vegetable processing plants in the region was monitored for water quality, samples being taken from the major steps in production. An average of these analyses taken at different times is shown in Tables 1-1 to 1-8. In

1975, practically no recycling of water was carried out in the region. However, since 1975 different plants have drastically reduced consumption and more and more recycling of water is the general practice. Most of the plants discharge water into municipal systems and thus volume of water as well as SS and BOD are important in calculating surcharge rates.

From the data in Tables I-1 and I-2 it can be seen that peeling and preparation of potatoes produced high wastestrength effluent that is high in SS. This necessitated an efficient screening operation and starch recovery in order to reduce wastestrength. The highest wastestrength in green beans was produced by blanching (Table I-3), and much of the research on this project has been directed toward alternate blanch methods (Section II). Preliminary tests showed that soaking and blanching of dry beans were the two major operations that contribute to wastestrength of the effluent from canning dry beans (Tables I-4 and I-5). Research findings have demonstrated that a high percentage of the wastestrength can be eliminated by reduced soaking times and eliminating blanching without affecting product quality (Section III).

The present method of peeling and preparation of hominy produces the highest wastestrength of any process studied (Table I-6). We have discussed alternate methods with processors based on research results on this project that would drastically reduce this pollution (Section IV). Most of the wastestrength from canning spinach and leafy greens continues to be produced by washing and blanching (Tables I-7), I-8). Because of the research on this project (Section II and V), much of it in cooperation directly with industry, the washing and blanching systems will be altered. The present washing system breaks up the leaves and stems badly, thus releasing more soluble constituents to the effluent. This also produces more loss of soluble constituents as well as nutrients during blanching and cooling (Section II, V).

Other monitoring of water quality of effluent from processing plants has been in conjunction with new screening equipment, recycling of water and cyclone separators for suspended solids. Also, preliminary research has been conducted on flocculants for removal of suspended solids from effluent from dry beans, hominy and potato processing with subsequent testing of the water (data not shown).

Table I-1. Water quality of effluent at different stages of preparation of Irish potatoes for fried potato sticks.[z]

Operation	Total solids mg/l	Suspended solids mg/l	Settleable solids ml/l	COD mg/l
Washer	780	200	30	200
Abrasive peel	4410	1780	60	4050
Slicing	1600	140	6	1250
Washer (slices)	2760	360	12	2500
Total flow				

[z] Production capacity - 8500-9000 lb/hr.
Water usage - 8,040 gal/hr.

Table I-2. Water quality of effluent at different stages of preparation of Irish potatoes for canning.[z]

Operation	Total solids mg/l	Suspended solids mg/l	Settleable solids ml/l	COD mg/l
Washer	675	184	26	410
Scrubbers	3100	1128	140	1756
Flume	784	104	12	608
Total flow	2376	264	76	1262

[z] Production capacity - 400 cs/hr, 6/10 cans.
Water usage - 12,950 gal/hr.

Table I-3. Water quality of effluent at different stages of preparation of green beans for canning.[z]

Operation	Total solids mg/l	Suspended solids mg/l	Settleable solids ml/l	COD mg/l
Washer	120	0.6	8	80
Blancher	4205	15	26	3150
Cooling	214	0.8	12	165
Total flow	1425	1.8	17	384

[z] Production capacity - 18 tons/hr
Water usage - 17,500 gal/hr.

Table I-4. Water quality of effluent at different stages of preparation of Red Kidney dry beans for canning.[z]

Operation	Total solids mg/l	Suspended solids mg/l	Settleable solids ml/l	COD mg/l
Soaking	2640	310	9	2124
Fluming	3104	270	11	2396
Blancher	11040	890	21	9927
Total flow	4284	360	14	3310

[z] Production capacity - 450 cs/hr-24/300 cans.
Water usage - 11,900 gal/hr.

Table I-5. Water quality of effluent at different stages of preparation of pork and beans for canning.[z]

Operation	Total solids mg/l	Suspended solids mg/l	Settleable solids mg/l	COD mg/l
Soaking	4978	420	16	4540
Fluming	5214	490	17	2824
Blanching	10800	1080	41	9386
Total flow	4380	460	14	3760

[z] Production capacity - 440 cs/hr-24/300 cans.
Water usage - 11,500 gal/hr.

Table I-6. Water quality of effluent at different stages of preparation of hominy for canning.[z]

Operation	Total solids mg/l	Suspended solids mg/l	Settleable solids mg/l	COD mg/l
Peeling	64200	44080	1240	59800
Bleaching	12400	10140	245	9876
Cooking	7940	3570	87	5766
Fluming	4160	2194	68	3570
Total flow	24800	17840	292	18960

[z] Production capacity - 410 cs/hr-24/300 cans.
Water usage - 10,600 gal/hr.

Table I-7. Water quality of effluent at different stages of preparation of spinach for canning.[z]

Operation	Total solids mg/l	Suspended solids mg/l	Setteable solids mg/l	COD mg/l
Washing	792	480	3.2	386
Blanching	1770	848	10.8	1134
Cooling	247	122	0.6	81
Total flow	591	487	2.8	284

[z] Production capacity - 10 ton/hr.
Water usage - 18,200 gal/hr.

Table I-8. Water quality of effluent at different stages of preparation of turnip greens for canning.[z]

Operation	Total solids mg/l	Suspended solids mg/l	Settleable solids mg/l	COD mg/l
Washing	473	124	0.9	248
Blanching	804	486	1.7	671
Cooling	148	73	0.2	72
Total flow	446	314	0.4	269

[z] Production capacity - 10 ton/hr.
Water usage - 17,900 gal/hr.

II. Washing, blanching and cooling.

Most of the research data conducted on wash water volumes, detergent, blanch method, blanch time and cooling has been published (Appendix A-1, A-2, A-3, A-4).

One additional study on turnip greens indicated that steam blanching could be substituted for water blanching without greatly affecting quality of canned turnip greens (Table II-1). Shearpress values, ascorbic acid and liquor color were higher on steam blanched spinach and stemminess was rated lower by a sensory panel as compared to water blanched samples.

The use of detergent resulted in slightly darker canned product as shown by the 'L' values. This was reflected in lower color scores by the sensory panel. Also, the product was slightly tougher as measured by the shearpress and higher in ascorbic acid. Higher water volumes decreased 'a' value indicating less greenness, and the product was less firm as shown by lower shearpress values. Furthermore, the canned product that was washed in greater volumes of water was rated lower in color. Greater physical damage to the raw product by the use of larger volumes of water during washing apparently did significantly affect quality of canned turnip greens.

An additional series of experiments were conducted to measure the change in water quality with repetitive washing,blanching and cooling lots of spinach. Rinse water after the 2nd wash was added to the 2nd recycle tank and water levels maintained in the other tanks by movement of a constant volume from d to a tanks. During the first washing experiment (Table II-2) there was a gradual increase in TS, TSS and SS. The recycle tanks built up more slowly in these constituents. There was a steady increase in nitrates in all tanks with no indication of leveling off. The COD build up in the washing tanks was fast initially, but after a few wash cycles it appeared to level off or increase at a very slow rate around 300 mg/l.

The first blanching and cooling experiment (Table II-3) showed a steady increase in TS but there appeared to be a leveling off after 22 batches. The rate of increase for TS was slower in the cooling water. There was a slow build up of TSS

and SS with the rate being slower in the cooling water. This particular experiment was conducted in two parts. The first part included samples 1-10 on the first day. The following day samples 11-22 were completed. The tanks of blanch water and cool water were left to stand overnight and the same waters used on the second day of the experiment. For this reason, the bacteria had a chance to reduce the organic compounds overnight thereby causing a sharp decrease in nitrates and COD. There was a steady rate of increase in both nitrates and COD on each day with the blanching water increasing in greater amounts than the cooling water.

The second washing experiment showed basically the same trends as in Table II-2. TS, TSS and SS increased slowly with little accumulation (Table II-4). Nitrates steadily increased with some indication of leveling off. The settling tank remained low in nitrates. COD levels were relatively high initially, but there was no great increase after the first 5 batches.

The second blanching and cooling experiment (Table II-5) showed basically the same results as in Table II-3. TS steadily increased with a slight leveling off after 7 batches. TSS and SS increased slowly with little build up. Nitrates and COD showed a steady rate of increase with no sign of leveling off.

The results of the steam blanching and cooling experiment using different blanch times showed an irregular pattern in TS TSS, COD and nitrates. There was a decrease in nitrates and COD up to 2 minutes of blanching in steam, then very little change to 4 minutes (Table II-6). Values for cooling water did not relate to blanch time.

In canned spinach from the same lots, there were no differences indicated with regard to either drained wt, shearpress, nitrates, organoleptic panel ratings or OD of liquor (Tables II-7 and II-8). The CDM 'a' value indicated a slight decrease in greenness with each blanch cycle for the first blanching experiment (Table II-7). No difference was detected between cooling and not cooling. However, the CDM 'a' value in the second blanching experiment (Table II-8) indicated

an increase in greenness in blanch cycles 7 to 10. In any event there did not appear to be any great change in quality with repetitive washing, blanching and cooling.

Neither steam blanching time nor cooling had any effect on drained wt, shearpress, or OD of liquor of canned spinach (Table II-9). Blanched samples that were not cooled contained slightly more nitrates than did blanched, cooled samples (Table II-9). This indicates that the cooling water leached out additional nitrates from the spinach. The taste panel ratings seemed to indicate better color, texture and flavor with shorter blanch times. No difference was detected due to cooling. The CDM 'a' value also showed slightly more greenness in the samples with shorter blanching times.

Table II-1. Effect of detergent wash, volume of wash water and blanch method on quality of canned turnip greens.

Main effect	Hunter CDM L	Hunter CDM a	Hunter CDM b	Drained wt(g)	Shearpress lb/150g	Sensory Panel Color	Sensory Panel Stemminess	Sensory Panel Texture	Ascorbic acid mg/100g	Liquor color O.D. 475nm
Blanch										
Water	22.99	.74	12.15	301.7	770	6.84	6.19	6.70	20.18	.183
Steam	22.85	.65	12.07	306.9	786	6.76	5.82	6.67	28.03	.241
F Value	1.90NS	3.78NS	2.21NS	2.61NS	4.33*	1.21NS	11.52**	0.06NS	367.45**	65.78**
Detergent Wash										
Control (H_2O)	23.02	.72	12.16	302.7	771	6.89	611	6.73	24.55	.211
0.5% Metzo	22.88	.67	12.05	305.9	786	6.71	5.90	6.64	23.67	.214
F Value	4.91*	.86NS	3.73NS	1.03NS	3.84*	5.54*	3.89NS	0.41NS	4.65*	0.11NS
Volume of Wash Water l/min										
1	22.80	.86	12.03	302.5	805	6.95	6.05	6.69	24.07	.205
3	23.01	.71	12.14	302.9	766	6.79	5.96	6.69	24.13	.213
10	22.94	.51	12.16	307.5	763	6.66	6.00	6.68	24.13	.220
F Value	0.99NS	16.36**	1.92NS	1.01NS	12.73**	4.95*	0.22	0.001	0.01NS	1.38NS

* Significant at 5% level.

** Significant at 1% level.

NS Not significant.

ash Cycle	TS[1] (g/1)	TSS (g/1)	SS (ml/1)	NO_3 (mg/1)	COD (mg/1)	Wash Cycle	TS (g/1)	TSS (g/1)	SS (ml/1)	NO_3 (mg/1)	COD (mg/1)
1-a[2]	.320	.050	0.20	7.7	128	8-a	.772	.436	2.0	16.4	249
b	.232	.018	0.08	5.4	200	b	.500	.182	1.6	14.6	246
c	.252	.018	T	4.4	74	c	.196	.032	T	8.4	166
d	.252	.016	T	4.2	120	d	.228	.020	T	5.2	130
2-a	.480	.252	0.8	7.8	213	9-a	.796	.514	2.0	18.8	252
b	.280	.044	T	6.4	87	b	.568	.210	1.2	11.0	194
c	.224	.040	T	4.3	89	c	.328	.040	T	8.8	143
d	.184	.010	T	4.3	102	d	.136	.018	T	5.4	128
3-a	.628	.350	0.4	9.6	124	10-a	.788	.568	1.6	15.8	240
b	.276	.098	T	9.0	108	b	.516	.166	1.2	14.0	222
c	.168	.012	T	4.8	77	c	.308	.044	T	9.8	158
d	.224	.008	T	4.2	90	d	.108	.022	T	5.7	136
4-a	1.016	.528	0.16	11.0	130	11-a	1.028	.480	2.0	19.9	369
b	.436	.184	0.12	12.0	94	b	.796	.268	1.2	21.8	298
c	.260	.028	T	5.2	92	c	.144	.020	T	11.0	142
d	.340	.074	T	4.6	92	d	.204	.040	T	6.2	141
5-a	.828	.616	1.8	16.0	146	12-a	1.136	.608	1.2	20.5	316
b	.360	.164	1.4	14.0	172	b	.564	.322	0.8	24.6	358
c	.332	.048	0.4	5.8	73	c	.260	.032	T	11.6	290
d	.184	.020	T	5.4	120	d	.164	.060	T	6.8	164
6-a	.580	.356	1.2	17.0	137	13-a	1.184	.704	1.6	23.5	365
b	.380	.026	2.0	17.0	118	b	.828	.414	2.0	28.1	383
c	.220	.026	T	16.2	94	c	.264	.072	T	14.8	232
d	.196	.020	T	5.0	90	d	.528	.050	T	7.6	219
7-a	.996	.518	2.0	17.5	296						
b	.740	.198	1.2	19.4	152						
c	.396	.174	T	9.2	96						
d	.260	.022	T	5.1	60						

[1]TS-Total Solids, TSS-Total Suspended Solids, SS-Settleable Solids, NO_3-Nitrates, C)D-Chemical Oxygen Demand.

[2]a-first wash
b-second wash
c-1st recycled tank
d-2nd recycled tank

Table II-3. Effect of sequence of water blanching and cooling on water quality in spinach processing.[1]

Sample No.	Water Blanching					Cooling				
	TS[1] (g/l)	TSS (g/l)	SS (ml/l)	NO_3 (mg/l)	COD (mg/l)	TS (g/l)	TSS (g/l)	SS (ml/l)	NO3 (mg/l)	COD (mg/l)
1	.472	.056	0.2	19	40	.176	.010	0.01	9	44
2	.332	.072	0.2	35	60	.184	.014	0.01	12	48
3	.688	.116	0.3	56	112	.240	.032	0.01	16	108
4	.972	.118	0.4	70	132	.276	.041	0.01	22	108
5	1.016	.098	0.4	96	140	.300	.020	0.01	27	140
6	1.104	.100	0.5	125	276	.368	.044	0.01	31	104
7	1.276	.096	0.8	130	356	.456	.042	0.08	36	224
8	1.424	.104	0.8	154	552	.468	.078	0.01	37	208
9	1.620	.082	0.4	175	596	.560	.080	0.08	42	312
10	1.684	.106	0.4	200	356	.556	.086	0.04	48	318
11	2.196	.106	0.4	26	520	.540	.100	0.04	5	84
12	1.752	.126	0.4	42	400	.604	.110	0.04	5	80
13	1.844	.116	0.4	64	456	.656	.120	0.06	6	120
14	2.268	.122	1.6	79	516	.672	.124	0.06	6	144
15	2.280	.128	1.2	94	880	.728	.102	0.06	6	204
16	2.528	.110	2.8	125	688	.764	.130	0.08	9	208
17	2.772	.128	1.2	138	608	.788	.142	0.10	7	200
18	2.840	.226	0.8	163	640	.832	.138	0.10	10	216
19	3.072	.178	0.8	178	980	.820	.194	0.10	10	248
20	3.280	.144	0.8	200	776	.956	.184	0.10	11	260
21	3.348	.216	0.8	218	788	.944	.152	0.40	12	260
22	3.448	.190	1.2	238	888	1.116	.150	0.40	8	240

[1] TS-Total Solids, TSS-Total Suspended Solids, SS-Settleable Solids, NO_s-Nitrates, COD-Chemical Oxygen Demand

Table II-4. Effect of washing on water quality in spinach processing.[1]

Wash Cycle[2]	TS[3] (g/1)	TSS (g/1)	SS (ml/1)	NO3 (mg/1)	COD (mg/1)
1-a	.252	.042	.12	9.6	216
b	.140	.020	.04	6.3	216
c	.176	.008	T	3.5	224
2-a	.312	.126	.20	16.9	224
b	.184	.028	.40	9.4	240
c	.160	.036	T	3.6	224
3-a	.668	.094	.22	22.2	224
b	.312	.020	.20	12.8	256
c	.180	.012	T	4.1	216
4-a	.692	.284	2.0	28.0	264
b	.360	.106	2.0	15.8	216
c	.168	.052	T	5.1	224
5-a	.724	.540	2.0	31.9	248
b	.384	.084	2.0	19.2	232
c	.188	.036	.4	6.4	224
6-a	.748	.496	2.4	37.9	240
b	.404	.180	1.6	22.2	232
c	.184	.020	.1	6.8	240
7-a	.788	.380	1.6	40.2	312
b	.504	.044	2.8	24.7	312
c	.196	.034	.1	7.6	264
8-a	.960	.420	4.0	46.0	240
b	.540	.386	2.0	28.1	272
c	.292	.060	1.2	9.0	152
9-a	.980	.626	2.4	50.9	240
b	.584	.672	2.0	30.1	280
c	.228	.062	.8	10.2	184
10-a	1.060	.720	2.4	54.1	288
b	.624	.248	1.2	34.0	312
c	.248	.074	.6	11.3	280

[1] Successive 8 lb. lots were washed in 200 lb. water tanks per wash cycle.

[2] a-1st wash
b-2nd wash
c-recycle water

[3] TS-Total Solids, TSS-Total Suspended Solids, SS-Settleable Solids, NO_3-Nitrates, COD-Chemical Oxygen Demand.

le II-5. Effect of sequence of water blanching and cooling on water quality in spinach processing.[1]

nch le	TS[2] (g/1)	TSS (g/1)	SS (ml/1)	NO3 (mg/1)	COD (mg/1)	Cool Cycle	TS (g/1)	TSS (g/1)	SS (ml/1)	NO3 (mg/1)	COD (mg/1)
	.256	.010	T	27	164	1	.128	.002	T	8.2	28
	.344	.034	0.4	54	188	2	.168	.004	T	14.6	40
	.480	.058	0.8	79	180	3	.184	.010	0.1	19.0	92
	.624	.072	1.6	102	204	4	.220	.012	0.2	25.4	96
	.808	.074	2.0	12	292	5	.344	.034	0.4	32.3	124
	.888	.090	0.1	147	324	6	.296	.046	0.6	37.7	128
	1.108	.098	0.1	172	264	7	.288	.052	0.8	43.5	144
	1.200	.104	0.1	200	400	8	.332	.062	0.6	49.7	152
	1.428	.110	0.1	229	436	9	.416	.068	0.8	59.1	178
	1.520	.114	2.0	258	456	10	.456	.086	0.8	64.6	193

Successive 8 lb. lots were blanched in 320 lb. of water and cooled in 200 lb. of water in kettles.

TS-Total Solids, TSS-Total Suspended Solids, SS-Settleable Solids, NO_3-Nitrates COD-Chemical Oxygen Demand.

Table II-6. Effect of steam blanching and cooling on water quality in spinach processing.

	Steam Blanched[1]				Cooling			
Blanch Time (min)	TS (g/1)	TSS (g/1)	COD (mg/1)	NO_3 (mg/1)	TS (g/1)	TSS (g/1)	COD (mg/1)	NO_3 (mg/1)
½	2.674	.686	1189	1246	.125	.146	64	84
1	3.116	1.019	529	910	.172	.125	27	51
1½	2.906	.762	463	709	.221	.138	19	59
2	3.081	.800	346	637	.188	.112	16	47
2½	2.200	.320	390	800	.197	.134	66	53
3	2.195	.390	341	878	.262	.139	40	60
3½	1.867	.507	204	573	.240	.402	10	59
4	2.740	1.400	384	838	.216	.128	46	61

[1]TS-Total Solids, TSS-Total Suspended Solids, COD-Chemical Oxygen Demand, NO_3-Nitrates.

Table II-7. Effect of blanching and cooling on some quality attributes of canned spinach.

Blanch Cycle	Drained wt (g)	Shear-press (kg/100g)	Panel Rating[1] Color	Texture	Flavor	Color Attributes L	-a	b	NO_3 (mg/l)	OD Liquor 475nm
1-a[2]	268	55	7.0	7.5	7.0	21.4	0.6	10.8	138	.323
b	264	69	7.0	7.0	7.0	21.3	0.6	10.7	124	.348
2-a	261	53	8.0	7.5	7.5	21.5	0.6	10.8	145	.324
b	251	61	7.0	8.0	7.5	21.0	0.6	10.6	129	.326
3-a	276	50	8.0	6.5	6.5	21.6	0.9	10.9	138	.361
b	232	56	8.0	6.5	6.5	21.1	0.4	10.6	108	.337
4-a	251	54	7.5	7.0	7.0	20.9	0.4	10.6	123	.320
b	273	67	7.5	7.5	6.5	21.2	0.6	10.7	158	.340
5-a	276	55	9.0	7.5	7.0	21.4	0.7	10.8	132	.358
b	235	62	8.0	7.0	7.0	20.7	0.7	10.7	110	.290
6-a	273	67	8.5	8.0	8.0	21.2	0.7	10.8	130	.310
b	238	68	8.0	7.5	6.5	21.4	0.4	10.8	103	.319
7-a	274	51	8.0	6.5	7.0	22.2	0.5	11.4	124	.410
b	250	66	7.3	7.0	7.0	22.5	0.5	11.8	104	.375
8-a	271	56	7.0	7.0	6.0	22.5	0.5	11.3	133	.395
b	231	58	6.0	6.0	5.0	22.4	0.5	11.3	111	.360
9-a	278	65	6.0	5.0	6.0	22.5	0.5	11.3	137	.377
b	246	66	6.0	7.0	6.0	22.3	0.5	11.3	113	.385
10-a	285	61	6.0	6.0	6.0	22.4	0.5	11.3	161	.370
b	266	71	6.0	6.3	6.0	22.6	0.5	11.3	118	.350
11-a	247	71	6.0	7.0	6.5	22.3	0.1	11.3	118	.310
b	292	72	7.0	6.5	6.5	2217	0.1	11.7	125	.347
12-a	293	63	6.5	7.0	7.0	22.7	0.1	11.7	139	.330
b	256	62	6.5	7.0	7.5	22.5	0.1	11.7	115	.315
13-a	276	70	7.0	6.0	5.0	21.2	0.4	11.7	130	.332
b	254	69	7.0	7.0	6.0	21.5	0.4	11.7	121	.250
14-a	268	64	7.0	6.0	6.0	21.8	0.4	11.1	144	.301
b	250	58	8.0	7.0	7.0	21.8	0.1	11.1	117	.261
15-a	277	76	7.0	6.0	6.0	21.4	0.1	11.1	141	.302
b	255	60	6.0	7.0	6.0	21.7	0.1	11.1	115	.296
16-a	291	103	7.0	6.0	7.0	21.8	0.1	11.1	131	.293
b	267	72	7.0	6.0	7.0	22.0	0.1	11.1	113	.287
17-a	285	63	8.0	7.0	6.0	21.0	0.1	11.1	160	.302
b	258	54	7.0	6.0	7.0	21.0	0.1	11.1	97	.339
18-a	286	54	7.0	6.0	6.0	21.6	0.1	11.1	132	.301
b	251	57	6.0	6.0	6.0	21.5	0.1	10.8	93	.290

Table II-7.Continued.

Blanch Cycle	Drained wt (g)	Shear-press (kg/100g)	Panel Rating[1] Color	Texture	Flavor	Color Attributes L	-a	b	NO_3 (mg/1)	OD Liquor 475nm
19-a	275	69	7.0	7.0	7.0	21.8	0.1	11.1	150	.271
b	276	66	7.0	7.0	7.0	21.8	0.1	11.1	133	.287
20-a	288	57	8.0	7.0	7.0	21.8	0.1	11.1	152	.346
b	274	66	7.0	6.0	7.0	21.7	0.1	11.1	135	.310
21-a	275	58	6.0	7.0	6.0	21.8	0.1	11.1	169	.328
b	267	68	7.0	6.0	6.0	22.1	0.1	11.1	152	.292
22-a	275	65	7.0	7.0	7.0	21.8	0.1	11.1	131	.321
b	256	71	6.0	7.0	6.0	21.7	0.1	11.1	129	.270

[1]Rated on scale of 10-best to 1-poor.

[2]a-blanched--not cooled
b-blanched--cooled

Table II-8. Effect of blanching and cooling on some quality attributes of canned spinach.

Blanch Cycle	Drained wt (g)	Shear-press (kg/100g)	Panel Rating[1] Color	Texture	Flavor	Color Attributes L	-a	b	NO_3 (mg/l)	OD Liquor 475nm
1-a[2]	251	105	7.5	8.0	7.0	21.3	0.0	11.2	158	.310
b	218	126	7.0	6.5	6.0	21.0	0.0	11.0	123	.275
2-a	249	99	8.8	8.5	9.0	21.1	0.0	11.1	159	.335
b	228	105	7.0	7.5	7.5	21.8	0.0	11.5	114	.285
3-a	252	102	8.3	8.0	8.0	20.6	0.0	10.9	137	.315
b	241	105	9.0	8.0	8.0	20.6	0.0	10.9	129	.305
4-a	249	108	7.8	8.0	7.5	21.2	0.0	11.4	160	.305
b	235	113	6.5	8.0	7.5	21.8	0.0	11.6	112	.290
5-a	249	112	8.0	7.8	8.0	20.7	0.0	11.0	155	.290
b	243	84	7.5	7.5	7.5	22.2	0.0	11.9	127	.300
6-a	252	78	7.0	8.0	7.5	21.4	0.0	11.3	144	.325
b	233	80	8.0	8.0	8.0	20.7	0.0	10.9	112	.300
7-a	234	83	7.0	7.5	7.5	22.2	0.7	11.2	142	.260
b	241	92	7.3	8.0	7.0	22.1	0.7	11.2	141	.300
8-a	256	91	7.5	8.0	7.8	22.5	0.7	11.2	151	.269
b	231	103	8.3	8.0	7.5	22.4	0.7	11.2	136	.298
9-a	262	73	8.0	8.0	8.0	22.0	0.7	11.2	161	.213
b	240	79	7.5	7.0	7.0	22.4	0.7	11.2	128	.250
10-a	252	103	6.5	8.0	7.0	21.7	0.7	11.8	149	.289
b	244	107	8.5	8.5	8.5	22.1	0.7	11.3	127	.253

[1]Rated on scale of 10-best to 1-poor.

[2]a-blanched--not cooled
b-blanched--cooled

Table II-9. Effect of steam blanching and cooling at various times on some quality attributes of canned spinach.

Blanch Cycle	Drained wt (g)	Shear-press (kg/100g)	Panel Rating[1] Color	Texture	Flavor	Color Attributes L	a	b	NO_3 (mg/l)	OD Liquor 475 nm
½-a	257	116	8.0	7.7	8.0	22.8	0.0	10.7	216	.405
b	279	95	8.7	8.3	8.0	20.1	0.0	9.7	.86	.385
1 -a	263	100	9.0	9.0	8.3	22.1	0.0	9.3	208	.385
b	257	84	6.7	6.7	6.7	22.6	-0.8	9.8	148	.350
1½-a	288	104	7.8	8.0	7.7	20.6	-0.4	9.3	223	.383
b	239	98	7.7	7.7	7.7	23.0	-0.3	9.8	150	.374
2 -a	281	79	7.5	7.0	7.5	21.7	0.7	11.1	180	.370
b	229	88	8.5	8.0	8.5	21.8	0.4	11.2	148	.325
2½-a	274	104	8.0	8.0	8.5	23.0	0.4	11.9	210	.370
b	214	83	8.0	7.5	8.0	22.1	0.4	11.3	130	.310
3 -a	278	95	8.0	7.5	7.5	22.9	0.4	11.8	182	.380
b	217	80	5.0	5.5	5.0	21.3	0.4	k0.9	104	.275
3½-a	274	90	7.0	7.0	5.5	22.2	0.3	11.5	199	.345
b	247	104	6.5	7.0	7.0	22.2	0.3	11.5	148	.330
4 -a	267	91	7.0	7.0	7.0	23.5	0.3	12.2	202	.355
b	245	72	7.0	6.5	6.5	22.6	0.3	11.7	158	.345

[1]Rated on scale of 10-best to 1-poor.

[2]a-steam blanched--not cooled
b-steam blanched--cooled

III. Bean type, soak time, soak temperature and storage of canned dry beans.

This study was instigated as a result of the high wastestrength of the effluent from processing dry beans found in the preliminary survey of water quality (Section I). Alternate methods of processing appear to offer great reductions in wastewater strength when evaluating data from this research (Appendix B-1). More detailed information has been recorded in a Master's thesis (Appendix D-5).

The materials and methods of this research have been described in the journal article (Appendix B-1) and in the thesis. Bean types significantly influenced the COD, total phosphorus (TP) and TSS of the effluent from soaking dry beans. Navy beans generated much higher wastestrength than pinto and Red Kidney. Longer soak times and higher temperatures leached out more soluble constituents, thus greater wastestrength. Among the soak treatments, which included different concentrations of EDTA and malic and citric aicds in comparison to tap and deionized water controls, acid treatments increased COD due to the chemical structure and probably more leaching.

In the canned product which was set up as a factorial experiment with 3 bean types, 11 treatments, 3 soak temperatures, and 3 soak times, the canned beans were stored for 3,6, and 18 months prior to sensory evaluation and other objective determinations. There were significant differences among bean types (Table III-1). Navy beans had more splits but were rated lower in sensory color. Drained weight was higher on pinto beans while Red Kidney rated higher in general appearance possibly due to low % splits and color brightness.

Soaking treatments did not greatly affect quality except that most of the EDTA and acid treatments produced better color. However, only EDTA did not influence COD (Appendix B-1). Soaking times did not greatly influence quality as shown by 'a' values, sensory color and appearance (Table III-1), yet drained weights and % splits were higher and shearpress values lower on beans soaked 14

hours. A higher soak temperature (35°C) increased % splits and decreased shearpress values but did not affect other quality parameters appreciably. The effects of 18 month storage on quality parameters varied although the canned beans became slightly lighter as shown by the 'L' values and redder by the 'a' values. This effect was probably produced by the slow change during storage due to the EDTA and acid treatments.

Table III-1. Quality attributes of canned dry beans as affected by bean type, soaking conditions and duration of storage.

Main effects	Drained wt(g)	% Splits	Shear values lb/150g	CDM L	CDM a	CDM b	Color Color	Color General appearance
Bean Type								
Navy	172b[z]	68.1a	226a	53.8a	2.9c	15.4a	6.8c	7.0b
Red Kidney	173b	21.6c	230a	20.4c	10.6a	2.8c	7.5a	7.6a
Pinto	177a	45.6b	178b	40.4b	8.6b	13.6b	7.2b	7.1b
Soaking Solution								
200 ppm EDTA	174bcde	45.0b	206def	37.7de	7.4bc	10.4de	7.0cd	7.1cd
400 ppm EDTA	178a	46.5b	197f	37.9cde	7.7a	10.6bcd	7.1bc	7.1cd
600 ppm EDTA	177ab	42.8b	202ef	38.4abc	7.8a	10.7bc	7.3b	7.3bc
0.1% Malic acid	173cde	44.6b	211cde	37.8cde	7.2bc	10.5cd	6.8de	7.0de
0.2% Malic acid	171ef	44.7b	221abc	38.3bcd	7.2bc	10.6bcd	6.9cde	7.1cd
0.3% Malic acid	170f	44.1b	232a	39.0a	7.5ab	11.0a	7.6a	7.5ab
0.1% Citric acid	175bcd	43.3b	209de	38.1bcd	7.1c	10.5cd	7.1bc	7.1cd
0.2% Citric acid	172def	44.8b	213bcd	38.7ab	7.3bc	10.8ab	7.7a	7.6a
0.3% Citric acid	171ef	44.6b	223ab	38.9a	7.5ab	11.0a	7.8a	7.7a
Tap water	175bcd	48.0a	207def	37.4e	7.1c	10.2e	6.7e	6.8e
Deionized Water	175abc	47.7a	203def	37.7de	7.0c	10.2e	6.9cde	7.9de
Soak Time								
3 hr	171b	41.9c	241a	37.4c	7.3a	10.5b	7.1b	7.1b
6 hr	169c	45.1b	204b	38.2b	7.3a	10.7a	7.2ab	7.3a
14 hr	181a	48.2a	189c	39.0a	7.4a	10.7a	7.3a	7.3a
Soak Temperature								
15°C	172b	44.4b	240a	37.5b	7.2b	10.4c	7.0c	7.0b
25°C	175a	45.1b	208b	38.5a	7.6a	10.8a	7.4a	7.4a
35°C	174a	48.2a	187c	38.5a	7.3b	10.6b	7.2b	7.2b
Storage								
3 mo	175a	42.7b	215a	37.6b	6.4b	10.1c	7.4a	7.3a
6 mo	174a	47.8a	206b	37.2c	6.6b	10.6b	7.1b	7.2a
18-24 mo	172b	44.8b	213a	39.8a	9.1a	11.7a	7.1b	7.2a

[z] Mean comparisons within each variable of a quality attribute established using Duncan's Multiple Range Test, 5%.

IV. Method of peeling and bleaching corn for hominy.

The present method of peeling hominy used by the regional industry involves cooking of the dry corn in 1.5 to 2% caustic soda (NaOH) for 20 to 30 minutes followed by peeling in a reel with water sprays. All pericarp, germ and other residue is washed into the effluent. The experimental peeling method that was compared with the conventional method in this study involved dipping the dry corn in 10% boiling caustic soda for 1 to 5 minutes followed by 5 to 20 minutes of holding in steam. A 3 minute dip and 10 minute holding time was the better procedure since the corn held for longer times was more difficult to bleach.

The yield of drained canned hominy from the two methods of peeling was the same (Table IV-1). Corn gained approximately 50% in weight during peeling, bleaching and pre-cooking and the remainder during retorting for 29 minutes at 116°C. The experimental dip method resulted in a smoother peel of corn although the tips were more difficult to remove. The corn peeled by the conventional method was more difficult to bleach because of the deeper penetration of caustic and longer time exposure. Apparently in the dip method there is more uniform exposure to lye which resulted in a smoother peel. There appeared to be very little difference in color and firmness of canned hominy although tips remaining on the grains in the dip-peeled corn affected the rating for tips (Table IV-2). In general, the corn peeled by the dip method was more attractive although data did not definitely reflect this observation.

It was noted that bleaching in HCl instead of $NaHSO_3$ resulted in a better color in canned hominy (Table IV-3). However, shearpress values were slightly higher, indicating firmer grains. Corn peeled by the dip method was lighter in color as shown by the higher 'L' values. Also, the HCl-bleached corn was higher in 'L' values and more attractive.

The main advantage of the dip method would be the smoother peel and the ease of bleaching the corn after peeling, However, the pericarp, caustic and other

residue could be removed as heavy solid residue with a minimum of water in the first stage of scrubbing; whereas, a second stage could be used for the final rinsing of corn. Apparently there is very little difference in total COD removed in the peeling operation regardless of the method (Table IV-4). However, there is a greater proportion of COD removed in the bleaching step following the dip method but most of the COD is removed in the initial peel in the conventional method. Samples that were dip-peeled and bleached with HCl were lower in average COD of the residue. Soluble sugars, starch and other carbohydrates are removed at each step in the preparation process as shown by the distribution of COD values.

The dip method of peeling hominy offers several advantages over the conventional method that should be considered by the canning industry. Also, changing the method of residue removal following caustic treatment by isolating the heavy residue would significantly reduce COD of the effluent. This would involve adding an additional peeling reel or modifying the present peeling equipment.

Table IV-1. Comparison of the yield of hominy from conventional and experimental methods of peeling corn.[z]

Method	Rep..	After bleach (g)	After pre-cook (g)	After canning (g)	Yield[y]
Conventional	1	264	317	461	230.5
	2	265	321	480	240.0
	3	240	299	464	232.0
Experimental	1	267	294	467	233.5
	2	257	316	468	234.0
	3	280	352	536	268.0

[z] 200g samples of dry corn peeled.

[y] Yield (lb) of drained hominy per 100 lb dry corn.

Table IV-2. Effect of peel method on color, firmness and sensory quality of canned hominy.[z]

		CDM			Shearpress	Sensory[z]	
Method	Rep.	L	-a	b	lb/150g	General appearance	tips
Conventional	1	75.5	3.0	7.1	290	9	9
	2	74.3	2.2	8.2	268	8	9
	3	76.2	2.9	7.6	355	8	9
Experimental	1	75.8	3.2	7.7	326	9	8
	2	74.7	2.9	7.4	308	9	8
	3	77.6	3.4	8.3	354	8	7

[z] Rated by panel of 4 judges on scale of 10-best to 1-poor.

Table IV-3. Effect of method of peeling and bleaching on quality of canned hominy.

Peel method	Bleach method	Rep.	CDM L	CDM -a	CDM b	Shearpress lb/150g	Sensory[z] color
Conventional	$NaHSO_3$	1	72.0	2.1	8.3	216	8
	$NaHSO_3$	2	73.7	2.6	7.7	255	8
	HCl	1	74.4	2.7	8.4	298	9
	HCl	2	74.3	2.8	7.3	284	9
Experimental	$NaHSO_3$	1	75.5	3.0	6.1	268	8
	$NaHSO_3$	2	74.9	2.8	6.3	257	8
	HCl	1	77.6	3.2	7.6	291	9
	HCl	2	76.9	3.0	7.2	284	10

[z] Rated by a panel of 4 judges on a scale of 10-best to 1-poor.

Table IV-4. Comparison of Chemical Oxygen Demand (COD) of effluent from conventional and experimental peeling of corn for hominy.

Method	Rep.	Preparation Step[z] Peel	Rinse	Bleach	Soak	Cook	Average
		mg/l effluent					
Conventional	1	35,360	6,400	14,560	4,800	7,700	13,776
	2	39,480	3,480	10,200	3,960	6,900	12,816
Conventional Neutralized[y]	1	24,400	13,360	4,560	13,360	7,360	12,608
	2	26,040	7,080	8,640	13,320	8,040	12,624
Experimental	1	7,040	10,048	25,728	9,280	11,328	12,685
	2	5,640	4,320	32,520	8,880	14,880	13,248
Experimental Neutralized	1	4,800	5,040	20,360	11,328	10,688	10,443
	2	4,080	3,840	19,320	8,040	16,800	10,416

[z] For 100g of corn the following water volumes were used: rinse-2500 ml; bleach- 500; soak-200; and boil-500.

[y] Sample neutralized with HCl after peeling.

V. Spinach and Leafy Greens Washing System

A. Spinach

1. Water quality

The industrial washer produced a greater amount of total suspended solids (TSS), total solids (TS), settleable solids (SS) as well as chemical oxygen demand (COD) and nitrates (NO_3) (Tables V-1, V-2, V-3). This was evidenced by the large differences in values between the two systems. The sampling sites could possibly contribute to part of the differences between TS and SS as shown by earlier workers (36). In the experimental washing system the sample was taken from the top of the settling tank, in which all heavy particles had settled to the bottom. Whereas, in the industrial washer, the samples were taken from beneath the reels and from the top of the two paddle washers. Heavy sand and other particles would have settled out from the water in the paddle washers. The NO_3, TS, and COD were expected to be lower in the experimental washer rather than the industrial washer since there is much more physical damage to the produce in the industrial washer, which causes more sugars, NO_3 and organic acids to be leached out. Similar results on TSS, BOD, and COD were reported by Wright et al. (36) when comparing the prototype washer and conventional washers. The runs or days show the combined data of the two systems in which there was some variability among days in both 1978 and 1979 (V-1,2,3). There was a significant difference for TSS, SS, COD, and NO_3. The time of day that the sample was taken was significant only for TSS in 1978 indicating that the product was uniform in soil residue. In 1979, a great difference in the amount of soil on the raw product which increased TS and SS (Tables V-2,3) affected the results.

When looking at the interaction of system and runs, the industrial system produced water with more waste in the 2nd and 3rd runs as evidenced by the large difference in values between the two systems in TSS, TS, COD

and nitrates (Table V-4,5). The regulation of the overflow in the experimental washer and heavier product flow through this system in the 1st run probably accounted for this smaller difference in water quality. The greater physical damage imposed on spinach washed in the industrial washer also contributed to the interaction.

There was greater variability among the times of day for TSS and TS between the two systems that contributed to the interaction of systems and times (Table V-6). In all cases the industrial washer produced more waste but the differences were much greater at certain sampling times (1st, 3rd, 5th, 7th).

2. Canned Spinach

Washing systems had no significant effect on the CDM color when color measurements were made on the whole spinach (Tables V-7,8,9). However, when the color of the pureed spinach was measured, the 'a' values of the samples washed in the experimental washer were higher (Tables V-8,9). Time of day had a significant influence on color of pureed samples. Some of the variation in color between runs and time of day could be accounted for by changes in the type of spinach, savoy and semi-savoy, being processed.

The interaction between runs and times on 'L' value (pureed) of canned spinach was due primarily to the lighter colored spinach in the first 3 samples of the 2nd run (Table V-10).

Spinach from the experimental washer generally showed greater amounts of ascorbic acid and nitrates than the industrial washer (Tables V-11,12,13). This was probably caused by more physical damage to the product in the industrial washer and the leaching of solutes. In 2 of the 3 studies, drained weight of spinach canned from the experimental washer was significantly lower than that canned after being washed in the industrial washer. The drained weight, ascorbic acid, nitrates and shearpress values varied between days of

operation. This variation on different days was probably due to the leaf type as the product varied from smooth-leaf to savoyed-leaf between days. Time of day had some influence on quality of the spinach. The quality factors affected here varied between studies (Tables V-11,12,13). Type of spinach processed at a particular time had a definite effect on most quality attributes. The smooth-leaf type was damaged more by the industrial washer; whereas, very little damage was evident when washed by the experimental washer. Neither washing system, runs nor times of day affected the amount of sand or grit in canned spinach.

The interaction between system and runs on ascorbic acid of canned spinach was caused by greater differences in ascorbic acid during runs (Table V-14). Phosphates were slightly higher in samples from the first run of the experimental washer; whereas, the opposite was true for the industrial washer (Table V-15). The decrease in ascorbic acid between the first and second runs of the experimental washer was greater than that occurring with the industrial washer; ascorbic acid levels in samples from the second runs from both systems were similar. Although both washers produced samples of equivalent toughness during the first run, the second run samples washed in the industrial washer were more firm than those from the experimental washer.

The interaction of systems and times on nitrates of canned spinach indicated that there was more variability in the 1st and 7th sampling time between the two systems (Table V-16). The highest amount of nitrates were found at the 4th sampling time which was the only time the water from the experimental systems was higher in nitrates.

The interaction of runs and times was contributed largely by the wide variation in nitrates during the 2nd run. The only explanation offered for this difference might be changes in spinach type (V-17).

The interaction of runs and times on shearpress values of canned spinach was caused by the tougher spinach during part of the 1st run and the first sample of 2nd run (Table V-18). More resistance to shear was attributed to the fact that more smooth-leaf spinach was processed during the 1st run and the beginning of the 2nd run.

The interaction of runs and times was significant for canned spinach when looking at the drained weight (Table V-19). The high drained weights at the 2nd, 3rd and 5th time of the 2nd run contributed to part of the interaction. Drained weights were low in most samples from the 3rd run.

3. Frozen Spinach

When comparing the two systems on the frozen spinach, there was no significant difference in either ascorbic acid, 'L' value or 'a/b' ratio (Table V-20). Again, as the canned spinach, there was a significance in ascorbic acid and CDM 'L' value when comparing runs or days (Table V-20). The time of day was significant for ascorbic acid, being the highest earlier in the morning and the values were lowest at the later time of sampling. This cannot really be explained since the washed samples from the earlier times were held longer after washing before processing, yet the later samples came from spinach that remained on the truck longer.

B. Turnip and Mustard Greens

1. Water Quality.

The data from a 4 hour run on each of turnip and mustard greens were analyzed as one experiment. The effluent from the industrial washer was higher in TSS, TS, SS, COD and nitrates than the effluent from the experimental washer (Table V-21). Again, the industrial washer produced more physical damage to the product, although it was not as distintive as in spinach. Effluent from the mustard greens were significantly higher in TSS, TS, SS, and COD. Time of sampling during the day did not affect

water quality except in TSS. The value for TSS was much higher at the 1st sampling time, indicating more soil on the greens from the first load.

The interaction of systems and type of greens on TSS indicated that there was a greater difference in the lb/ton of TSS between the systems when washing mustard greens (Table V-22).

When looking at the interaction of systems and time, the TSS of the effluent from the industrial washer was much higher than that of the experimental washer (Table V-23). Most of the interaction was caused by the large difference between systems in the 1st sample and small differencein the 4th effluent sample from the experimental washer.

2. Canned turnip and mustard greens.

There was no significant differences between the two washing systems, whether the sample was whole or pureed, for color of the samples according to the 'L' value and 'a/b' ratio (Table V-24). Whereas, the mustard greens were lighter in color than the turnip greens as noted in the 'L' value (pureed and whole), and 'a/b' ratio (pureed). Also, there was a difference in color of the greens at different sampling times, as shown by the 'L' value (whole) and 'a/b' ratio (whole and pureed). Neither washing system, type of greens nor time of sampling had a significant effect on liquor color.

The interaction of type of greens and time of sampling on liquor color of canned turnip and mustard greens demonstrated that there was more variation in liquor color of canned mustard (Table V-25). The interaction was caused by the larger differences of the mustard at the 3rd, 5th and 6th sampling times and the small differences of the turnips at the 5th and 7th sampling times.

When comparing the two washing systems, there was no significant difference for drained weight, grit, ascorbic acid, NO_3 and shearpress values (Table V-26). The mustard was lower in drained weight, NO_3, and grit but higher in ascorbic

acid. The time of sampling during the runs had a significant effect on all quality attributes measured except NO_3 values and grit. The chloride was not removed from the samples before the NO_3 analyses. This effect was expected since the greens varied between loads and between turnip and mustard greens.

The interaction of type of greens and time of sampling on drained weight of canned turnip and mustard was significant (Table V-27). Generally, the drained weight was significantly higher on turnip than on mustard greens but the fact that the difference in drained weight was much greater at the 2nd and 5th sampling time produced an interaction between type of greens and time.

C. Bacterial Count of Wash Water

Total plate counts on the effluent from washing spinach and leafy greens were inconsistent during the operation on different days, depending on the amount of soil and grit on the raw product. There were significant differences between sampling sites in water from both the industrial and experimental washers (Table V-28), also, there was a difference in bacterial count between runs or days of operation. In most instances, the highest counts were found in water from the first washer. However, there were no differences in counts between washing systems. Recycling water did not increase counts. In fact, there was a tendency for counts to be lower on recycled water. Wright et al (36) reported that total plate counts were lower on water that was recycled. There were no significant interactions on total plate counts due to washing systems, runs and time of sampling. The most important differences occurred in samples from different days of operation.

In turnip and mustard greens, similar results were obtained except that mustard greens were lower in counts than turnip greens (Table V-29). Again, water from different sampling sites showed significant differences but there were no differences between washing systems. In recycling of water, if sufficient make-up water was added, the bacterial counts were not higher than the first wash water.

Table V-1. Main effects of washing systems, runs and time of day on water quality of the effluent from washing spinach, 1978.

Variable	Suspended Solids lb/ton	Total Solids lb/ton	Settleable Solids lb/ton	COD lb/ ton	Nitrates lb/ ton
System					
Industrial	12.15	19.63	49.10	4.76	1.30
Experimental	5.49	7.23	18.61	1.02	0.34
$LSD_{.05}$	0.43	1.75	5.98	0.50	0.17
RUNS (days)					
1st	9.65	13.60	47.17	1.54	0.88
2nd	8.01	13.88	33.17	2.84	0.95
3rd	8.80	12.81	20.69	4.31	0.61
$LSD_{.05}$	0.17	NS	7.33	0.605	0.21
Time					
8:30	8.10	10.69	29.73	2.44	0.75
9:00	8.75	12.87	34.62	2.66	0.74
9:30	9.84	13.51	38.57	2.75	0.79
10:00	7.37	12.61	35.04	3.12	0.74
10:30	9.97	15.51	27.60	3.01	1.08
11:00	8.62	14.35	34.18	3.30	0.78
11:30	9.10	14.47	37.26	3.01	0.80
$LSD_{.05}$	0.26	NS	NS	NS	NS

$LSD_{.05}$ - least significant difference at 5% level.
NS - Non-significant

Table V-2. Main effects of washing systems, runs and time of day on water quality of the effluent from washing spinach, 1979.

Variable	Suspended solids kg/mt	Total solids kg/mt	Settleable solids l/mt	COD kg/mt
System				
Industrial	11.27	18.77	29.94	20.66
Experimental	2.25	3.97	5.05	4.57
LSD .05	2.73	2.19	7.12	3.47
Runs				
1st	4.67	8.32	13.55	11.34
2nd	8.85	14.42	21.44	13.90
LSD .05	2.73	2.19	7.12	NS
Time				
8:15	9.91	13.31	21.80	15.88
9:00	9.81	17.14	35.27	16.11
9:45	5.81	10.41	21.89	15.34
10:30	5.44	10.15	7.25	9.59
11:15	5.51	11.48	14.99	7.75
12:00	4.09	5.70	3.76	11.03
LSD .05	NS	3.80	12.33	6.01

Table V-3. Main effects of washing systems, runs, and time of day on water quality of the effluent from washing spinach, 1979.

Variable	Suspended solids kg/mt	Total solids kg/mt	COD kg/mt	Nitrates lb/ton
System				
Industrial	4.46	9.50	9.72	17.50
Experimental	2.84	3.94	3.63	6.52
LSD .05	.76	1.09	1.58	1.73
Runs				
1st	3.49	5.54	8.15	8.12
2nd	3.82	7.90	5.20	15.89
LSD .05	NS	1.09	1.58	1.73
Time				
9:30	2.05	5.04	4.83	9.95
10:00	2.36	4.69	6.82	8.76
10:30	3.29	5.09	7.21	11.23
11:00	3.31	5.56	6.41	13.06
11:30	2.72	6.36	6.78	10.73
12:00	3.03	6.34	5.75	12.01
1:15	3.29	6.50	7.81	12.54
1:45	2.57	7.50	7.51	15.06
2:15	4.86	8.31	5.32	15.00
2:45	6.32	10.55	7.39	12.68
3:15	5.61	7.38	6.58	11.67
3:45	4.43	7.31	7.69	11.41
LSD .05	1.87	2.68	NS	NS

Table V-5. Interaction of systems x runs on water quality of the effluent from washing spinach, 1979.

	Total solids (Feb.-March)	COD (April-May)	Nitrates (April-May)
Industrial			
Run I	14.27	12.29	11.96
Run II	23.26	7.15	4.29
Experimental			
Run I	2.36	4.00	23.04
Run II	5.57	3.25	8.75
LSD .05	3.05	2.23	2.43

Tablev-4. Interaction of Systems X Runs on water quality of effluent from washing spinach, 1978.

Variable	Suspended Solids lb/ton	Total Solids lb/ton	COD lb/ ton	Nitrate lb/ ton
Run 1				
Industrial	11.26	16.99	2.13	1.26
Experimental	8.04	10.21	0.94	0.50
Run 2				
Industrial	11.91	21.53	4.53	1.57
Experimental	3.90	6.23	1.14	0.32
Run 3				
Industrial	13.06	20.36	7.63	1.03
Experimental	4.50	5.26	0.98	0.20
$LSD_{.05}$	0.24	3.10	0.86	0.30

$LSD_{.05}$ - Least significant difference at 5% level.

Table V-6.Interaction of Systems X Times on suspended and total solids of effluent from washing spinach, 1978.

Variable	Times 8:30	9:00	9:30	10:00	10:30	11:00	11:30
Suspended Solids (lb/ton)							
Industrial	12.85	11.90	13.23	8.72	13.24	11.26	13.82
Experimental	3.36	5.60	6.45	6.01	6.71	5.97	4.32
$LSD_{.05}$	0.0002						
Total Solids (lb/ton)							
Industrial	18.19	18.99	19.08	16.59	22.26	20.12	22.15
Experimental	3.20	6.75	7.93	8.63	8.76	8.59	6.79
$LSD_{.05}$	4.62						

$LSD_{.05}$ - Least significant difference at 5% level.

Table V-7. Main effects of washing systems, runs and time of day on quality of canned spinach, 1978.

Variable	Color Difference Meter "L" Whole	"L" Pureed	a/b Whole	a/b Pureed	Liquor Color (OD-475 nm)
System					
Industrial	24.2	23.6	0.136	0.061	0.357
Experimental	23.7	23.5	0.136	0.064	0.326
$LSD_{.05}$	NS	NS	NS	NS	NS
Runs (days)					
1st	24.44	23.7	0.150	0.084	0.430
2nd	23.91	23.8	0.148	0.057	0.771
3rd	23.54	23.3	0.112	0.048	0.253
$LSD_{.05}$	NS	0.31	0.010	NS	NS
Time (hr)					
8:30	25.1	24.0	0.154	0.066	0.327
9:00	23.9	23.5	0.138	0.064	0.333
9:30	23.5	23.5	0.140	0.066	0.436
10:00	22.9	23.0	0.142	0.067	0.411
10:30	24.0	23.7	0.133	0.056	0.294
11:00	25.6	23.6	0.127	0.063	0.293
11:30	23.8	23.9	0.125	0.056	0.297
$LSD_{.05}$	NS	0.5	NS	NS	NS

$LSD_{.05}$ - Least Significant Difference at 5% level.

NS - Non-significant

Table V-8. Main effects of washing systems, runs and time of day on quality of canned spinach, 1979.

Variable	Drained weight (g)	Whole Spinach CDM 'L'	Whole Spinach CDM '-a'	Whole Spinach CDM 'b'	Pureed Spinach CDM 'L'	Pureed Spinach CDM '-a'	Pureed Spinach CDM 'b'	Liquor color (OD-475nm)
System								
Industrial	241	26.3	.19	11.3	26.3	.27	12.1	.277
Experimental	230	26.4	.09	11.4	26.2	.38	12.1	.304
LSD .05	7	NS	NS	NS	NS	.06	NS	NS
Runs								
1st	240	25.6	.01	11.0	26.3	.38	12.0	.289
2nd	231	27.1	.28	11.7	26.2	.27	12.2	.293
LSD .05	7	1.1	.14	.6	NS	.06	.1	NS
Time								
8:15	242	26.5	.06	11.5	26.4	.38	12.2	.297
9:00	243	25.8	.28	11.2	26.1	.18	11.9	.317
9:45	236	26.9	.11	11.6	26.6	.36	12.2	.287
10:30	233	26.9	.20	11.5	26.1	.25	12.1	.287
11:15	234	25.3	.08	10.8	26.3	.28	12.2	.291
12:00	226	26.5	.08	11.7	26.0	.51	12.1	.266
LSD .05	NS	NS	NS	NS	.3	.11	NS	.018

Table V-9. Main effects of washing systems, runs and time of day on quality of canned spinach, 1979.

Variable	Whole Color CDM 'L'	Whole Color CDM '-a'	Whole Color CDM 'b'	Puree Color CDM 'L'	Puree Color CDM '-a'	Puree Color CDM 'b'	Liquor color (OD-475nm)
System							
Industrial	27.4	.60	12.2	26.2	.05	12.7	.304
Expimental	27.3	.42	12.2	26.1	.12	12.8	.341
LSD .05	NS	0.14	NS	NS	.05	NS	.008
Runs							
1st	27.1	.36	12.2	26.3	.11	12.9	.307
2nd	27.5	.66	12.2	27.1	.06	12.6	.338
LSD .05	NS	0.14	NS	0.2	.05	0.1	.008
Time							
9:30	27.2	.49	12.0	26.3	.10	12.8	.328
10:00	28.7	.68	13.0	27.1	.03	13.3	.332
10:30	26.9	.58	12.1	25.5	.04	12.4	.309
11:00	27.6	.42	12.2	25.7	.17	12.5	.301
11:30	26.3	.34	11.7	26.3	.09	12.8	.333
12:00	27.4	.29	12.3	26.2	.12	12.8	.335
1:15	27.3	.63	12.0	25.9	.19	12.6	.325
1:45	27.3	.64	12.1	26.2	.04	12.8	.320
LSD .05	NS	NS	NS	0.4	.10	0.2	.017

Table V-10. Interaction of Runs X Times on "L" (Pureed) value of canned spinach, 1978.

Variables	8:30	9:00	9:30	10:00	10:30	11:00	11:30
	CDM "L" Values						
Runs							
1st	23.8	23.0	23.2	22.9	24.3	24	24.2
2nd	25.0	24.4	24.2	22.9	23.1	22.9	24.1
3rd	23.1	23.1	23.0	23.1	23.8	23.8	23.3
$LSD_{.05}$	.826						

$LSD_{.05}$ - Least Significant Difference at 5% level.

Table V-11. Main effects of washing systems, runs and time of day on quality of canned spinach, 1978.

Variable	Drained Weight(g)	Grit g/150g	Ascorbic Acid mg/100g	Nitrate PPM	Shearpress lb/150g
System					
Industrial	258.9	0.005	12.7	696	92
Experimental	269.4	0.004	14.3	766	92
$LSD_{.05}$	4.5	NS	0.8	4.8	NS
Runs(days)					
1st	263.6	0.003	8.4	644	122
2nd	275.9	0.004	14.9	1,053	89
3rd	252.9	0.007	17.3	495	65
$LSD_{.05}$	5.5	NS	1.0	5.8	13.8
Time					
8:30	261.8	0.003	13.4	633	107
9:00	268.2	0.005	14.2	657	88
9:30	271.0	0.004	13.8	640	91
10:00	264.8	0.006	13.0	936	77
10:30	262.4	0.004	14.4	831	90
11:00	263.7	0.005	13.5	822	92
11:30	257.1	0.004	12.2	594	101
$LSD_{.05}$	8.4	NS	NS	8.9	NS

$LSD_{.05}$ - Least Significant Difference at 5% level.

NS - Not Significant

able V-12. Main effects of washing systems, runs and time of day on quality of canned spinach, 1979.

ariable	Drained weight (g)	Grit g/300g	Ascorbic acid mg/100g	Nitrate ppm	Phosphates mg/ml	Shearpress lb/150g
ystem						
ndustrial	241	.0125	23.3	433	69	99
xperimental	230	.0120	24.4	487	78	96
SD .05	7	NS	NS	10	5	NS
uns						
st	240	.0170	26.3	390	76	95
nd	231	.0075	21.4	530	71	101
SD .05	7	.006	1.3	12	NS	NS
ime						
8:15	242	.0130	20.8	427	47	112
9:00	243	.0187	21.9	449	75	104
9:45	236	.0083	25.2	495	75	99
0:30	233	.0121	22.4	493	76	93
1:15	234	.0084	21.8	463	56	95
2:00	226	.0133	31.0	459	114	84
SD .05	NS	NS	2.3	18	9	11

ıble V-13. Main effects of washing systems, runs, and time of day on quality of canned spinach, 1979.

ıriable	Drained weight (g)	Grit g/300g	Ascorbic acid mg/100g	Nitrate ppm	Phosphates mg/ml	Shearpress lb/150g
ystem						
ıdustrial	246	.0089	24.6	501	99	90
xperimental	230	.0114	29.5	678	116	81
SD .05	5	.0024	1.7	37	NS	4
uns						
st	239	.0094	39.9	423	166	85
nd	245	.0109	14.2	755	49	87
SD .05	5	NS	1.7	37	18	NS
ime						
9:30	245	.0101	24.9	598	69	79
0:00	236	.0101	28.2	566	63	83
0:30	244	.0117	25.4	599	126	71
1:00	237	.0127	23.8	664	119	74
1:30	238	.0111	23.3	578	108	95
2:00	235	.0095	26.5	581	119	92
1:15	254	.0075	31.9	550	129	98
1:45	243	.0086	32.6	579	128	94
.SD .05	10	NS	3.4	NS	35	8

Table V-14. Interaction of Systems X Runs on ascorbic acid of canned spinach, 1978.

Variables	Ascorbic Acid Run 1	Run 2	Run 3
System			
Industrial	8.46	15.94	18.51
Experimental	8.40	13.77	16.00
$LSD_{.05}$	0.47		

$LSD_{.05}$ - Least Significant Difference at 5% level.

Table V-16. Interaction of Systems X Times on nitrates of canned spinach, 1978.

Variables	8:30	9:00	9:30	10:00	10:30	11:00	11:30
			Nitrates (PPM)				
System							
Industrial	709	709	665	884	870	868	654
Experimental	556	605	616	988	793	777	534
$LSD_{.05}$	12.57						

$LSD_{.05}$ - Least Significant Difference at 5% level.

Table V-17. Interaction of Runs X Times on nitrates of canned spinach, 1978.

Variables	8:30	9:00	9:30	10:00	10:30	11:00	11:30
			Nitrates (PPM)				
1st Run	778	720	605	794	521	505	588
2nd Run	528	818	858	1688	1533	1308	638
3rd Run	593	434	459	328	441	654	558
$LSD_{.05}$	1540						

$LSD_{.05}$ - Least Significant Difference at 5% level.

Table V-15. Interaction of systems x runs on quality of canned spinach, 1979.

	Phosphates mg/ml (Feb.-March)	Ascorbic acid(mg/100g) (April-May)	Nitrates ppm (April-May)	Shear lb/150g (April-May)
Industrial				
Run I	66.5	36.1	373.0	83.8
Run II	71.5	13.1	628.5	96.8
Experimental				
Run I	85.8	43.8	473.4	85.2
Run II	71.1	15.3	882.4	77.5
LSD .05	7.4	2.4	52.3	5.8

Table V-18. Interaction of Runs X Time on Shearpress values of canned spinach, 1978 .

Variables	8:30	9:00	9:30	10:00	10:30	11:00	11:30
	Shearpress (lbs/15og)						
1st Run	83	104	106	99	141	152	169
2nd Run	145	91	84	73	74	72	86
3rd Run	92	69	82	60	54	53	47
$LSD_{.05}$	36						

$LSD_{.05}$ - Least Significant Difference at 5% level.

Table V-19. Interaction of Runs X Times on drained weight of canned spinach, 1978.

Variables	8:30	9:00	9:30	10:00	10:30	11:00	11:30
	Shearpress (lb/15og)						
1st Run	263	270	273	276	254	257	252
2nd Run	267	292	284	274	280	272	262
3rd Run	255	243	256	245	253	262	257
$LSD_{.05}$	15						

$LSD_{.05}$ - Least Significant Difference at 5% level.

Table V-20. Main effects of washing Systems, runs, and time of day on quality of frozen spinach, 1978.

Variables	Ascorbic Acid mg/100g	CDM Values "L"	a/b
System			
Industrial	17.9	20.2	0.746
Experimental	16.2	20.2	0.767
$LSD_{.05}$	NS	NS	NS
Runs (days)			
1st	9.8	21.2	0.751
2nd	14.6	19.8	0.756
3rd	26.7	19.5	0.761
$LSD_{.05}$	3.0	1.2	NS
Time (hr)			
8:30	18.1	19.9	0.746
9:00	21.6	20.5	0.726
9:30	17.2	20.4	0.746
10:00	16.4	20.9	0.786
10:30	16.6	19.5	0.784
11:00	14.4	19.3	0.766
11:30	15.0	20.6	0.741
$LSD_{.05}$	4.6	NS	NS

$LSD_{.05}$ - Least Significant Difference at 5% level.

NS - Not Significant

Table V-21. Main effects of washing systems, runs and time of day on water quality of the effluent from washing turnip and mustard greens, 1978.

Variable	Suspended Solids lb/ton	Total Solids lb/ton	Settleable Solids lb/ton	COD lb/ton	Nitrate lb/ton
Systems					
Industrial	3.44	12.1	16.53	4.66	1.20
Experimental	1.10	3.6	4.83	1.28	0.37
$LSD_{.05}$	0.13	1.4	3.73	0.76	0.16
Runs					
1st	1.63	7.36	9.67	2.71	0.93
2nd	2.86	8.36	11.67	3.23	0.63
$LSD_{.05}$	0.13	1.4	3.73	NS	NS
Time					
8:30	3.95	6.14	12.81	2.95	0.77
9:00	1.53	6.35	9.51	2.25	0.66
9:30	1.81	8.28	8.84	2.52	0.80
10:00	1.36	7.80	8.79	3.43	0.80
10:30	2.37	8.11	11.16	3.05	0.70
11:00	2.47	9.50	14.17	3.38	0.92
11:30	2.34	8.66	9.49	3.34	0.79
$LSD_{.05}$	0.26	NS	NS	NS	NS

$LSD_{.05}$ - Least Significant Difference at 5% level.

NS - Not Significant.

Table V-22. Interaction of Systems X Times X Runs on suspended solids of effluent from washing turnip and mustard greens, 1978.

Variable	8:30	9:00	9:30	10:00	10:30	11:00	11:30
	Suspended Solids (lb/ton)						
Run 4							
Industrial	0.336	0.247	0.239	0.202	0.491	0.372	0.455
Experimental	0.063	0.085	0.092	0.103	0.185	0.189	0.203
Run 5							
Industrial	1.718	0.400	0.514	0.293	0.514	0.625	0.483
Experimental	0.081	0.142	0.178	0.182	0.167	0.227	0.193
$LSD_{.05}$	0.183						

$LSD_{.05}$ - Least Significant Difference at 5% level.

Table V-23. Interaction of Systems X Time on suspended solids of effluent from washing turnip and mustard greens, 1978.

Variable	8:30	9:00	9:30	10:00	10:30	11:00	11:30
	Suspended Solids (lb/ton)						
System							
Industrial	7.190	2.263	2.634	1.732	3.516	3.488	3.283
Experimental	0.504	0.800	0.950	0.997	1.233	1.457	1.389
$LSD_{.05}$	0.343						

$LSD_{.05}$ - Least Significant Difference at 5% level.

NS - Not Significant

Table V-24. Main effects of washing systems, runs and time of day on quality of canned turnip and mustard greens, 1978.

Variable	Color Difference Meter Values "L" Value(whole)	"L" Value (Pureed)	a/b (Whole)	a/b (Pureed)	Liquor Color (OD-475nm)
System					
Industrial	25.8	24.9	0.166	0.077	
Experimental	26.0	24.7	0.168	0.077	
$LSD_{.05}$	NS	NS	NS	NS	
Runs					
1st	25.6	23.6	0.186	0.071	
2nd	26.2	25.8	0.149	0.083	
$LSD_{.05}$	NS	0.31	0.10	0.02	
Time (hr)					
8:30	27.1	24.7	0.193	0.113	
9:00	25.9	24.7	0.182	0.082	
9:30	24.0	24.8	0.164	0.081	
10:00	27.4	25.2	0.167	0.062	
10:30	26.0	24.4	0.162	0.071	
11:00	24.8	24.8	0.143	0.062	
11:30	26.2	24.9	0.160	0.065	
$LSD_{.05}$	1.7	NS	0.04	0.02	

$LSD_{.05}$ - Lease Significant Difference at 5% level.

NS - Not Significant

Table V-25. Interaction of Runs X Times on drained weight of canned turnip and mustard greens, 1978.

Variable	Times 8:30	9:00	9:30	10:00	10:30	11:00	11:30
Runs							
4th	298.25	298.25	307.75	298.0	318.75	300.0	304.75
5th	292.75	252.50	299.25	303.5	300.25	297.25	291.5
$LSD_{.05}$	15.10						

$LSD_{.05}$ - Least Significant Difference at 5% level.

Table V-26. Main effects of washing systems, runs and time of day on quality of canned turnip and mustard greens, 1978.

Variable	Drained Weight (g)	Grit g/150g	Ascorbic Acid mg/100g	Nitrate (PPM)	Shearpress lb/150g
System					
Industrial	297.1	0.064	8.2	1393	454
Experimental	297.6	0.049	7.9	1379	471
$LSD_{.05}$	NS	NS	NS	NS	NS
Runs(days)					
1st	303.7	0.017	7.1	1900	472
2nd	291.0	0.048	9.0	871	453
$LSD_{.05}$	5.5	0.001	3.4	324	NS
Time(hr)					
8:30	295.5	0.003	8.4	1364	490
9:00	275.4	0.001	9.2	1357	463
9:30	303.5	0.209	5.9	1355	507
10:00	300.8	0.004	7.7	1424	414
10:30	309.5	0.003	8.0	1414	483
11:00	238.9	0.003	8.8	1356	436
11:30	298.1	0.003	8.3	1431	445
$LSD_{.05}$	8.4	0.002	2.4	229	65

$LSD_{.05}$ - Least Significant Difference at 5% level.

NS - Not significant

Table V-27. Interaction of Runs X Times on liquor color of canned turnip and mustard greens, 1978.

Variable	Times 8:30	9:00	9:30	10:00	10:30	11:00	11:30
Run 4	0.140	0.147	0.141	0.137	0.134	0.155	0.133
Run 5	0.168	0.159	0.228	0.190	0.221	0.212	0.185
$LSD_{.05}$	.0195						

$LSD_{.05}$ - Least Significant Difference at 5% level.

Table V-28. Comparison of bacterial counts of effluent from industrial and experimental washers in washing spinach for canning, 1978.

Systems x sites	Runs (4 hours each day) 1	2	3
Industrial washer			
1st reel	8.4×10^5 a[z]	6.6×10^5 b	2.0×10^6 a
1st paddle	5.3×10^5 b	2.5×10^5 c	2.0×10^6 a
2nd reel	2.1×10^5 c	1.6×10^4 e	3.1×10^5 b
2nd paddle	4.8×10^5 b	2.7×10^4 e	2.2×10^5 b
Average	5.1×10^5	2.4×10^5	1.1×10^6
Experimental washer			
1st washer	3.4×10^5 bc	3.5×10^5 c	1.6×10^6 a
2nd washer	4.5×10^5 b	8.4×10^4 d	7.1×10^4 c
1st recycle	2.0×10^5 c	6.3×10^4 d	5.5×10^5 b
2nd recycle	4.4×10^5 b	8.0×10^5 a	1.4×10^6 a
Average	3.6×10^5	2.0×10^5	9.0×10^5
Grand total	4.4×10^5 c[y]	2.2×10^5 b	1.0×10^6 a

[z] Mean separation within columns for systems x sites by Duncan's Multiple Range Test.

[y] Mean separation in row for runs by Duncan's Multiple Range Test.

Table V-29. Comparison of bacterial counts of effluent from industrial and experimental washers in washing turnip greens and mustard for canning, 1978.

Systems x sites	Type of Greens	
	turnip	mustard
Industrial washer		
1st reel	4.6×10^6 a[z]	1.2×10^6 a
2nd reel	1.9×10^6 c	2.5×10^5 bc
1st paddle	3.4×10^6 b	4.9×10^5 b
2nd paddle	2.9×10^6 b	1.2×10^5 c
Average	3.2×10^6	5.3×10^5
Experimental washer		
1st washer	1.7×10^6 c	1.3×10^6 a
2nd washer	1.3×10^6 c	$.9 \times 10^5$ c
1st recycle	2.9×10^6 b	6.4×10^5 b
2nd recycle	3.5×10^6 b	1.4×10^6 a
Average	2.4×10^6	8.6×10^5
Grand total	1.8×10^6 a[y]	6.9×10^5 b

[z] Mean separation within columns for systems x sites by Duncan's Multiple Range Test.

[y] Mean separation in row for type of greens by Duncan's Multiple Range Test.

VI. Solid waste fermentation, handling and storage.

The changes in regulations regarding landfills and other means of disposal promoted this study. One processing plant in the region utilized covered storage pits for Irish and sweet potato wastes before this research was begun. Because of the pausity of information on fermentation and handling, the nature of the problem and the interest of local processors a number of studies were conducted successively. Two articles have been published in journals (Appendix C-1, C-2) and one Master's thesis (appendix D-3). More detailed information can be found in the thesis on Irish potato wastes. The disposal of high alkalinity wastes constitutes one of the major problems in the region. Combining this fermented waste with poultry wastes or ground dry hay appears to be a practical and economical means of utilizing this material (Appendix C-1) but no progress has been made at this date to establish a commercial operation.

The materials and methods for this research are described in detail in the appendices C-1 and D-3. Similar studies were conducted on sweet potato high alkalinity wastes (Appendix C-2). Sweet potato wastes fermented more readily and there appeared to be less problems with obnoxious odors during fermentation. High temperatures have been shown to be the primary cause of off-odors in Irish potato wastes (Appendix C-1).

Separate storage experiments were set up to determine the storage life and changes in carbohydrates of Irish and sweet potato wastes.

A. Irish Potato Wastes

The fresh high alkalinity waste was analyzed and stored in 21 liter polypropylene containers with tightly fitting lids. One half of the containers were inoculated with fermented Irish potato waste and the other half was not inoculated. The experiment was begun in October and terminated in July, a period of 9-months. The containers remained outside under a covered porch. The

non-inoculated lots did not ferment and the carbohydrate composition and pH remained essentially the same as the original sample except for a decrease in starch content (Table VI-1). The hemicellulose increased during the storage period.

There was a decrease in starch and an increase in sugar content during fermentation. The pH reached 4.60 approximately in 7 days and remained constant during 9 months storage. The waste became much thinner after fermentation but did not change appreciably in viscosity during storage. There appears to be a gradual loss in starch content during storage after the initial 7 days of fermentation and a slight decrease in hemicellulose and cellulose, resulting in a decrease in dry matter of approximately 2%.

B. Sweet Potato Wastes

The fresh high alkalinity sweet potato waste was stored in 55 gal steel drums, 6 barrels approximately 2/3 full. The fresh waste was analyzed immediately and stored outside in the open except the barrels contained steel covers and a tarpaulin was used to prevent rain water from entering the barrels. Preliminary experiments showed that mold was a problem on the surface of the containers. Also, the industrial storage pits had been plagued with the same problem. It was found that either dehydroacetic acid (2%) or potassium sorbate (3%) solution sprayed on the top of the barrels the first week and at monthly intervals controlled the mold growth.

After 6 days of fermentation the pH of the waste had dropped to approximately 7.0, then there was a gradual decrease in storage (Table VI-2). There was very little decrease in dry matter during the first 3 months and a slight increase by 9 months as compared to the original. In contrast to Irish potato wastes (Table VI-1), there was a gradual decrease in sugars as well as starch during storage although not much change took place in starch after the initial fermentation.

There were variations in pectins, hemicellulose, cellulose, nitrates and total nitrogen during fermentation and storage but these values do not appear to change significantly. As stated previously, sweet potato wastes store well and there appears to be less problems of stability after fermentation, and no off-odor problems occurred in the various experiments conducted.

able VI-1. Effect of storage on composition of Irish potato high alkalinity peeling wastes (fresh wt. basis).

		pH	% Dry matter	% Total sugar	% starch	% Water soluble pectin	% Calgon soluble pectin	% Hemi-cellulose	% Cellulose
ample Rep.									
resh	1	11.30	17.6	.64	10.02	.37	.10	.25	.54
	2	11.30	17.4	.58	10.13	.38	.09	.28	.67
ermented	1	4.65	17.7	2.55	6.63	.44	.10	1.32	.94
7 days)	2	4.60	17.4	1.93	6.09	.45	.11	.78	.99
tored 4 mos									
ot inoculated	1	11.30	17.7	.69	10.02	.39	.10	.78	.71
	2	11.30	17.3	.53	8.38	.41	.11	.90	.73
	3	11.20	17.4	.74	7.81	.39	.08	.76	.69
noculated	1	4.60	15.6	2.33	2.75	.34	.07	.50	.71
	2	4.65	16.0	3.08	3.72	.30	.05	.48	.64
	3	4.65	16.2	2.33	3.31	.49	.10	.62	.66
tored 9 mos									
ot inoculated	1	11.30	17.6	.51	7.38	.47	.09	.92	.76
	2	11.30	17.2	.54	6.88	.44	.09	1.24	.81
	3	11.10	17.4	.59	6.69	.43	.08	1.27	.77
noculated	1	4.55	15.5	2.25	1.94	.43	.08	.67	.61
	2	4.50	15.6	2.90	1.75	.35	.05	.49	.54
	3	4.40	16.0	2.45	2.22	.43	.08	.86	.63

ble VI-2. Effect of storage on composition of sweet potato high alkalinity peeling wastes (fresh wt.basis).

orage	Rep.	pH	% Dry matter	% Total sugars	% Starch	% Pectins	% Hemi-cellulose	% Cellulose	NO_3 ppm	% Total nitrogen
esh	1	11.7	27.05	5.02	7.80	1.09	.78	1.24	478	.197
	2	11.6	25.03	5.50	7.30	.88	1.28	1.51	448	.230
	3	11.5	26.48	5.50	7.90	1.13	1.00	1.24	432	.233
Days	1	7.6	26.46	5.30	7.70	1.21	1.15	1.33	418	.157
	2	6.6	27.53	4.60	5.60	1.08	1.13	1.24	380	.207
	3	7.6	24.99	4.70	6.30	1.05	.90	1.11	390	.193
Month	1	6.9	24.84	4.20	6.20	.98	.84	.91	538	.197
	2	5.7	23.96	4.30	6.00	1.10	1.06	1.33	478	.230
	3	6.4	25.04	4.00	6.50	1.23	1.16	1.06	492	.230
Months	1	6.4	25.57	4.10	5.95	.69	.94	1.25	460	.187
	2	5.8	24.91	3.20	6.90	1.56	1.11	.98	506	.207
	3	5.1	23.25	3.80	5.80	1.25	.73	.85	432	.243
Months	1	5.9	26.39	3.75	4.83	.90	.96	2.40	430	.195
	2	5.7	30.20	2.88	5.71	.85	.91	1.68	515	.230
	3	5.0	28.70	3.36	4.67	.80	.89	2.11	438	.249

CONCLUSIONS

1. There are a number of vegetables canned in the Ozark region that produce high wastestrength effluent by the methodology presently used.
2. Alternate methods of preparation were demonstrated that could reduce the wastestrength of effluent from vegetable processing by over 50%.
3. Water can be recycled for washing, blanching, and cooling of vegetables without affecting quality of the canned product if properly done.
4. Processing of hominy produces the highest wastestrength of effluent of all canned products in the Ozark region. Suitable alternate methods were developed that could drastically reduce wasteloads.
5. Washing spinach and leafy greens utilizes more water in preparation than other vegetables. The use of a new prototype washing system reduced water use by 70% without affecting quality of the canned product.
6. One of the major causes of high pollutional strength in effluent from processing vegetables is the type of washing and transporting equipment used in the plant.
7. Wastestrength of effluent from canned dry beans can be significantly reduced by using the alternate methodology developed.
8. The quality of canned dry beans soaked for shorter times at $25^{o}C$ was equal to or better than that canned by commercially accepted procedures.
9. Low volume water sprays were as efficient for washing leafy greens as high volume sprays used by industry and physical breakage of the leaves was practically eliminated.
10. High alkalinity lye peeling wastes from Irish and sweet potato canning can be fermented and stored for 9 months without a great loss in total solids and carbohydrates.
11. Covered pits with screened gables are necessary for fermentation and storage of solid wastes in the Ozark region because of high rainfall.

12. Maintaining quality of the finished product is the primary concern of processors in the region although pollution abatement is rapidly becoming the first priority.

13. By cooperatively working with the vegetable processing industry in the region throughout the duration of this project better liquid and solid waste disposal systems have been installed in most of the plants. These include better separation and/or screening of suspended solids, better peeling methods, better solid waste utilization and/or disposal, more recycling of water and better control over blanching times and temperatures.

14. More research needs to be conducted to demonstrate systems of pollution abatement. Although wastestrength of effluent from processing vegetables in the region has been significantly reduced during the last 5 years much greater reductions could be accomplished during the next 5 years by appropriate technology without affecting quality of the finished product, even with normal expansion of production.

15. More research needs to be conducted on flocculation and separation of suspended solids under varying pH conditions. This particular problem is important not only from the standpoint of reducing surcharges but for recycling water as well.

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Appendices A through C are not included as part of this report. Information regarding these appendices may be obtained from the Arkansas Water Resources Research Center, University of Arkansas, Fayetteville.

APPENDIX D

Pages 74 thru 78
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